Heat Exchangers

Process Control

(Exercise 1)

Contents

List of Symbols

Cp_c Heat capacity of a cold medium

Cp_h Heat capacity of a hot medium

F_c Flow rate of a cold medium

F_h Flow rate of a hot medium

$T_\mathrm{c,1}$ Temperature of a cold medium entering the heat exchanger

$T_\mathrm{c,2}$ Temperature of a cold medium leaving the heat exchanger

$T_\mathrm{h,1}$ Temperature of a hot medium entering the heat exchanger

$T_\mathrm{h,2}$ Temperature of a hot medium leaving the heat exchanger

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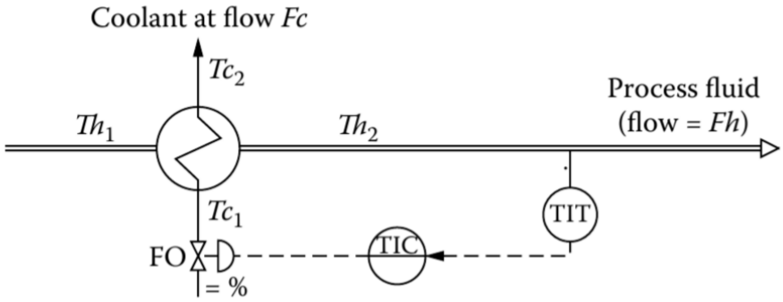
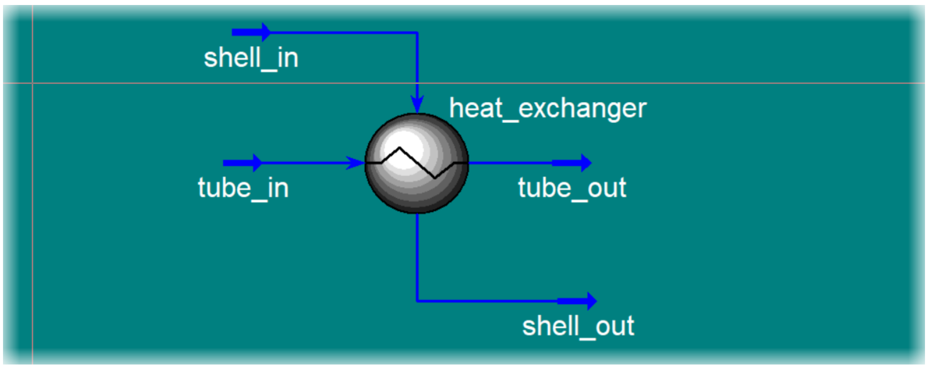


(a) Process scheme.



(b) Mathematical model (UniSim Design).

Figure 1: Scheme of a heat exchanger.

1 Introduction to Heat Exchangers

Fundamentals about heat exchangers [1, 2]:

+ Gain: $\frac{dT_{\mathrm{h},2}}{dF_{\mathrm{c}}} = \frac{Cp_{\mathrm{c}}}{F_{\mathrm{h}}Cp_{\mathrm{h}}}$.
+ Time delay: $T_{\mathrm{d}} = \frac{V}{F_{\mathrm{h}}}$.
+ Reduced load – large gain, fast and effective exchanger. More sensitive to disturbances and prone to cycling.
+ Large load – small gain, undersized, sluggish control.
+ In general, controller tuned for smaller loads.
+ Gain variation compensation – equal-percentage valve. Good solution if ΔT_{h} is constant. Otherwise feedforward gain compensation is required.
+ P controller (PB 100 %), I (set-point tracking) and D as well (for slower processes).
+ Sensors at representative locations, small time constants.
+ Flow control is recommended.

Energy balance equation:

$$Q = F_{\mathrm{h}}Cp_{\mathrm{h}}(T_{\mathrm{h},1} - T_{\mathrm{h},2}) = F_{\mathrm{c}}Cp_{\mathrm{c}}(T_{\mathrm{c},2} - T_{\mathrm{c},1}) \tag{1}$$

Table 1: Process (controlled) variables.

№	Stream	Variable
1	`shell_in`	Temperature
2	`shell_out`	Temperature
3	`tube_in`	Temperature
4	`tube_out`	Temperature

Table 2: Output (manipulated) variables.

№	Stream	Variable
1	`val_shell_in`	Actuator Desired Position
2	`val_shell_out`	Actuator Desired Position
3	`val_tube_in`	Actuator Desired Position
4	`val_tube_out`	Actuator Desired Position

2 Control Schemes of Heat Exchangers

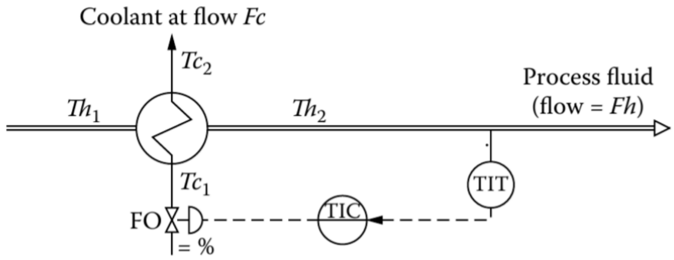
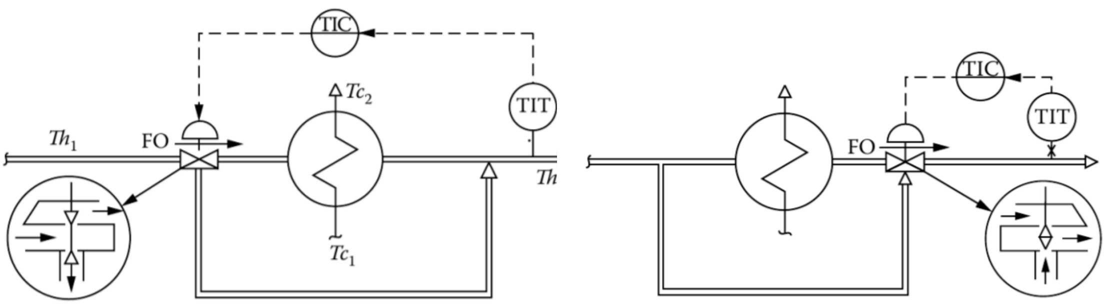


Figure 2: Basic control strategy of the heat exchanger.



(a) Valve is located before bypass.

(b) Valve is located after bypass.

Figure 3: Control scheme of heat exchanger with three-way valve.

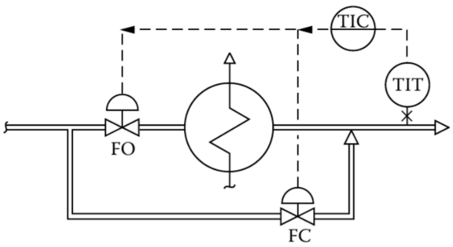
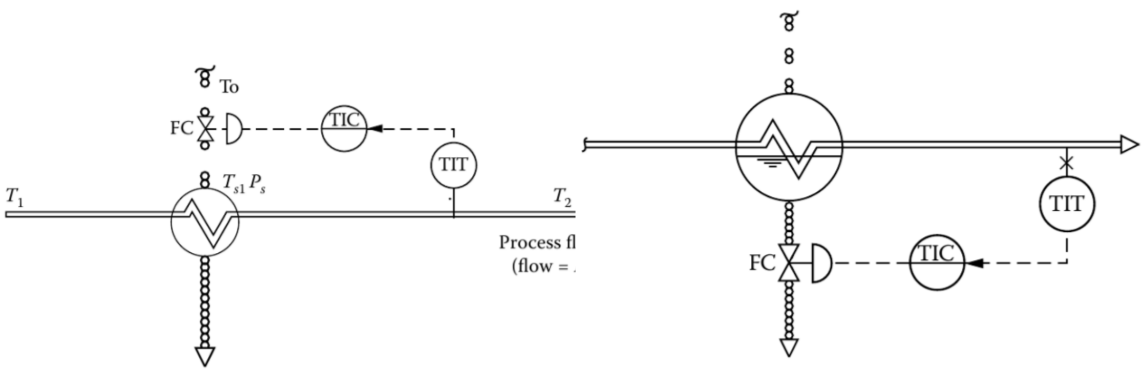


Figure 4: Control scheme of heat exchanger with two-way valve.



(a) Valve is located before bypass.

(b) Valve is located after bypass.

Figure 5: Control schemes of a steam heat exchanger.

3 Assignment

Analyzed model: `example_air_cooled_heat_exchanger_ss.usc` (UniSim Design R481)

Task 1

Compare the mathematical model with Figure 2. Try to indicate the heat medium and coolant.

Task 2

Design the controller as it is illustrated in Figure 2.

Task 3

Create suitable monitoring of significant variables within the model of studied process. Analyze the performance of designed controller.

References

[1] H. L. Hoffman, D. E. Lupfer, L. A. Kane, Bruce A Jensen, and B. G. Lipták. 19 distillation : Basic controls. In *Semantic Scholar*, 2008.

[2] M. King. *Process Control: A Practical Approach.* Wiley, 2016.